tivity of electrolytes in a mixture of solvents, and conductivity of a mixture of electrolytes in pure solvents. The tables of electromotive forces include those of normal cells, of transition cells, of concentration cells, the potential of simple electrodes, and divers unclassified electromotive force effects.

In addition to the above there are forty-seven pages devoted to data in general electricity and magnetism. Immediately following these are eight pages on radioactivity and ionization. The writer finds nothing on the Peltier effect or on the important subject of electrolytic thermo-electromotive force.

A bibliography is appended to every main division of the book. An alphabetical index would add much to the convenience of reference. The second volume for 1911 contains both a general and a special alphabetical list of all substances mentioned in both volumes.

HENRY S. CARHART

SPECIAL ARTICLES

AN ILLUSTRATION OF THE INFLUENCE OF SUBSTRATUM HETEROGENEITY UPON EXPERIMENTAL RESULTS

IN experimental breeding so much stress has been laid upon controlled fertilization that some other factors of importance for the obtaining of trustworthy results have been left too much out of account. The importance of heterogeneity in the substratum upon which the plants are grown as a possible source of error has been pointed out time and again. De Vries, for example, attaches great weight to this factor.

The purpose of this note is to give point to these warnings (too greatly neglected now) by showing how extrinsic influences may completely screen intrinsic tendencies.

In very extensive series of materials a positive correlation has been demonstrated between the weight of the seed planted and the number of pods on the plant into which it develops—that is, yield is higher in the plants from the heavier seeds. This is true without exception for twenty series, involving 13,099 plants, already published.[1] Further constants based on 4,856 plants, are given below. Here the coefficient of correlation, r_{wp}, shows the relationship between the weight of the seed planted (in the conventional units of .025 gram range) and number of pods per plant, while the second term of the regression straight line equation,[2]

$$p = \left(\bar{p} - r_{wp}\frac{\sigma_p}{\sigma_w}\bar{w}\right) + r_{wp}\frac{\sigma_p}{\sigma_w}w,$$

shows the absolute change in number of pods per plant for each unit change in seed weight.

Series	Number of Plants	Coefficient of Correlation and Probable Error	Regression Straight Line Equation
GGH.....	583	.208 ± .027	$p = 1.931 + .539w$
GGD.....	514	.159 ± .029	$p = -3.504 + .361w$
GGDD.....	342	.137 ± .036	$p = -1.967 + .279w$
GGHH....	396	.194 ± .033	$p = -2.321 + .513w$
GGD_2.....	449	.215 ± .030	$p = -4.861 + .436w$
GGH_2.....	499	.176 ± .029	$p = -1.037 + .485w$
GG.....	750	−.368 ± .021	$p = 17.418 - .403w$
LG.....	182	.066 ± .050	$p = 2.351 + .134w$
LL..... ...	1141	−.009 ± .020	$p = 7.245 - .012w$

The constants are in excellent agreement with those already published—fairly large and positive throughout—with the exception of the Golden Wax, the *L* series, and the *GG* culture of Burpee's Stringless. Those for the Golden Wax series, *LG* and *LL*, are sensibly zero; one is the smallest positive coefficient yet found while the other is negative in sign, though only a fraction of its probable error.

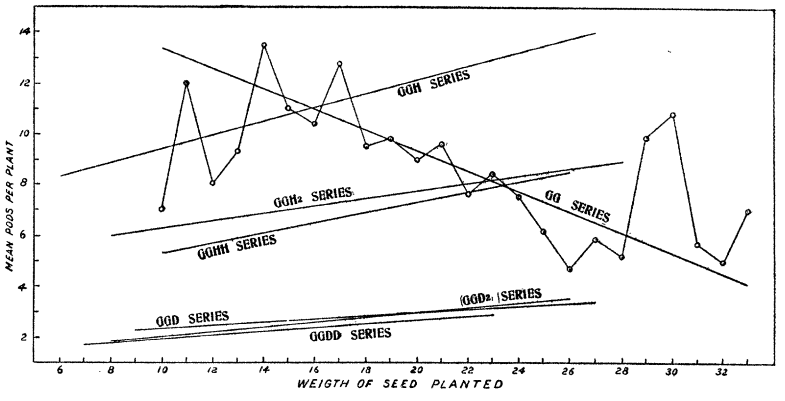
The coefficient for the *GG* series is in striking contrast to the others; not only is it numerically the largest value recorded, but it is negative in sign and unquestionably signif-

[1] Harris, J. Arthur, "The Relationship between the Weight of the Seed Planted and the Characteristics of the Plant Produced—I.," *Biometrika*, Vol. 9, pp. 11–21. See also *Amer. Breed. Mag.*, Vol. 3, pp. 293–295.

[2] p = pods per plant, w = weight of seed planted. The bars indicate the means and the sigmas denote the standard deviations of the characters in question. Through a slip in the copying of the manuscript which I overlooked in the proofs, the second term of the regression formula is given the negative sign on p. 14, *Biometrika*, Vol. 9. The values in the calculated equations are of course correct.

icant, being nearly eighteen times its probable error.

The comparison of the *GG* series with the other Burpee's Stringless cultures is forcibly brought out by the diagram. This shows the linear graduations (from the equations given in the table) of the number of pods per plant for various seed weight classes. Only the *GG* series, for which the empirical means are also



shown,[3] indicates a decrease in the number of pods associated with an increase in the weight of the seeds planted.[4]

The explanation of this result is simple. In each of these 29 experiments with the exception of the *LL*, *LG* and *GG* series, the seeds were individually labelled, thoroughly shuffled and planted at random over the field to counteract the possible heterogeneity of the soil.[5] In the case of the *LL* and *LG* series I suspected that the soil conditions were not strictly uniform, but the various "pure lines" were planted in numerical order across the field, just as is usually done. In the *GG* series the weight groups were planted in order across a garden plot *which was selected for its apparent uniformity of soil.* This was again in accordance with ordinary experimental practise.

But many unknowable factors are involved in the productive capacity of the soil and it appears that the particular parcel of ground selected, although only large enough to grow 750 plants, changed in productiveness from one side to the other. By chance the seeds were so planted that the smaller ones were given the best conditions. So great was the heterogeneity that it not only neutralized the influence of seed weight which is always demonstrated when experiments are made with proper refinements,[6] but actually brought about a negative correlation between weight of seed planted and number of pods produced *which is numerically the highest found in twenty-nine cultures!* Had the order of planting been reversed, both soil fertility and seed weight would have been active in the same direction, and an abnormally high positive correlation would almost certainly have been the result.

J. Arthur Harris
Cold Spring Harbor, L. I.,
June 10, 1913

[3] The inclusion of all the empirical means would have rendered the graph too confusing. Graphic tests made for each case affords no evidence that a curve of a higher order would be better than a straight line.

[4] For the *GGD*, *GGD*$_2$ and *GGDD* series the slope of the line is very slight. This is due simply to the fact that these cultures were grown under much more adverse conditions than the others, and such wide variation in number of pods per plant is not possible.

[5] The importance of this procedure has been emphasized in *Amer. Nat.*, Vol. 45, pp. 697–698, 1911; Vol. 46, p. 325, 1912.

[6] The seeds used in the *GG* series were the ancestors of those employed in all the other experiments with Burpee's Stringless. Thus there can be no criticism because of "differences between the pure lines used."